Lessons Learned System Number: EXT-10-002
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Submitted By: Multiple Sources
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Title of Lesson Learned:

Proper Tether System Design Reduces Public Risk and the Likelihood of Vehicle Damage.

Abstract:

Vehicle tether systems often represent the last opportunity to save a vehicle that is functioning in an unanticipated manner. Using a proper tether design and test setup, a tether can save a vehicle from damage and reduce risk to the public.

Triggering Event:

Tether systems serve two principle purposes.

1. They provide some protection against the vehicle suffering damage during testing. They do this by either restraining the vehicle's range of motion (translation or rotation) or by preventing its contact with the ground in the event of a thrust termination during flight. This is of prime importance to the operator's program,
2. They also prevent the vehicle from departing the launch site and posing a hazard to the public. This is of prime importance to people and property not associated with the activity.

These two purposes can be highly synergistic, and a good tether design will easily meet both. However, a poor tether design can be ineffective in serving one or both purposes, and at worst could contribute to hazards or failures that would not occur without their presence.

Lessons Learned and Recommendations:

The following paired lessons learned and recommendations represent tether advice gathered from reusable launch vehicle (RLV) operators as the result of several incidents involving loss of, or damage to, tethered launch vehicles.

Lesson 1 –

A tether is only as strong as its weakest point. Never think that a chain alone will stop a vehicle from flying away. If the vehicle decides to fly away at maximum throttle, something will break, probably the attach point on the vehicle.

Recommendation -

In order to restrain your vehicle from the bottom, use high strength cable to connect the vehicle to enough loose anchor chain to keep it from gaining too much altitude. Picking up links one at a time will keep the shock load down.

Lesson 2 –

Hanging tethers must have some stretch to them.

Recommendation –
For hanging tethers, use a dynamic recovery strap as a primary tether and a steel cable as a backup. Size the steel cable so that it comes into play about an inch or so after the maximum stretch of the strap.

Lesson 3 –

When using a palette loader type of crane, properly accounting for boom height and the change in tether length under load can limit the risk of damage to a launch vehicle. Keep in mind that crane booms flex and tires compress significantly on a shock load.

Recommendation –
Elevate your vehicle higher than you think you need to, remembering to account for tether stretch. Always elevate your tethered vehicle to a consistent height and a height that allows for margin to the shock load at the end of free fall. Consider using stand pipes or an off-balance pad to raise your vehicle. When using stand pipes, add some "sail area" at the bottom to catch the plume and knock the stands over. If using blow away stands, add some angles to them to prevent them from rolling away.

Lesson 4 –

Make sure the crane boom has no sharp edges that can cut the tethers. At least one vehicle was lost due to a severed tether system.

Recommendation –
To protect the tether consider adding covers to crane boom edges or using steel cables as a backup.

Lesson 5 –

Always use redundant tethers and ensure they can't slip off the attach point in any way.

Recommendation –
Ensure tethers are securely connected to the attach point and connecting hardware (nuts, bolts, shackles, etc.) are properly rated for the type of operation you are conducting. If using shackles, ensure that they positively lock.

Lesson 6 –

Dynamic climbing ropes make good shock absorbing tethers. However, don't tie knots in a tether line for attachment or shortening; under shock load the tether will break at the knot site.

Recommendation –

When possible, avoid tying knots in your tether system. Knots, bends, edges, and falls (shock loads) all reduce maximum breaking strength. When using climbing rope, develop an understanding of the design and construction of the rope as well as its use, care, and inspection. Ropes lose

elasticity and their ability to absorb energy when subjected to repeated falls. The useful life of your rope will depend on how often and how hard it is used. Maintaining a rope log will allow you to track rope usage and help you determine when to replace it.

Lesson 7 –

Make sure the tether cannot dip low enough to get underneath the vehicle, or catch on parts of the vehicle including, antennas, cameras, valves, and vents. The majority of damage suffered during tether testing was of this nature.

Recommendation –

Use a light bungee cord stretched to its maximum and connected to the tether every couple of feet; this causes the tether to stay bunched up and clear of the vehicle. Consider adding a length of PVC pipe over the end of the tether nearest to the vehicle to further prevent snagging. Another possible solution is adding a cage to the vehicle. In addition to protecting the vehicle, the cage can also serve as the tether attachment point.

Lesson 8 –

When conducting tethered launch activities always use a checklist. It's too easy to miss something if you don't.

Recommendation –

Develop and use a detailed checklist for conducting tethered operations. The checklist should include procedures for performing pre- and post-flight visual inspections of the tether system to identify any signs of damage (component fatigue, fracture, wear, corrosion, etc.). The checklist should also include procedures for conducting prelaunch safety briefings (observers clear of the operation, mishap response, etc.) and for verifying that fire fighting equipment is on hand and ready for use.

Questions regarding this lesson learned should be directed to 9-AWA-AST-LessonsLearned/AWA/FAA@FAA.gov.